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SOIL CONSERVATION IN IRRIGATED AREAS

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SOIL CONSERVATION IN IRRIGATED AREAS

Introduction:

In viewing the scattered and oasis-like agricultural communities of the western states, it is difficult for the casual observer to realize that more often than not every bit of greenery in sight is dependent upon the artificial and almost continuous application of water. In fact, the very presence of human habitations in many western localities depends upon the availability of water for irrigation. Thus it is understandable why so many land-users in the West continually emphasize the necessity for direct and determined attacks upon problems which have to do with the control and use of water. Under such circumstances, it is obviously impossible to develop and carry out comprehensive soil conservation programs without taking into account the varied land-use problems which are directly or indirectly related to availability of water supply and the utilization of such water for irrigation and other purposes. The importance of this relationship is further indicated by the fact that in most western states all water (whether it be natural stream flow, storm runoff, or underground water) is considered to be public property. Any sort of unauthorized interference with this water supply is prohibited by law and the appropriation of water for any use whatsoever must be in strict accordance with established legal procedures.

Such conditions naturally create complicated administrative problems in connection with the efforts of agricultural agencies (particularly the Soil Conservation Service) to develop and effectuate soil conservation programs which are appropriate for and applicable to irrigated areas, and which at the same time must be in conformity with the legislative acts authorizing such programs. In consideration of these difficulties, it is believed that a review in broad outline of the land management problems which are more or less common to all irrigated areas might be helpful to those who have the responsibility of making determinations as to the proper and permissible use of publicly financed facilities and resources which have been made available for the development and effectuation of soil conservation programs. Therefore, this paper has been prepared for the purpose of presenting the principal features of irrigation and drainage problems with particular reference to the preparation of farm conservation plans for land-users engaged in irrigation farming.

Importance of Irrigation Farming:

The importance of irrigation farming in connection with any soil conservation program for the western states is illustrated by the following facts which are taken from the "Statistical Abstract of the United States for 1939" published by the U. S. Department of Agriculture. In this abstract nineteen states are listed as irrigation states although the production of irrigated crops in four of these states is less than

one per cent of the total so produced. Two of the states listed (Arkansas and Louisiana) have a relatively high average annual rainfall (about fifty inches) and the type of agriculture considered as irrigation farming for statistical purposes is, of course, quite different from that practiced in arid or semi-arid sections.

Crops Grown by Irrigation in 19 States
As of 1929

(Latest Statistics Available)

States are listed in order of irrigated acreage.

No.	State	Total Acreage of Irrigated Crops	Per Cent of All Acreage under Irrigation
1	California	3,540,350	24.2
2	Colorado	2,291,927	15.7
3	Idaho	1,734,321	11.2
4	Montana	1,343,035	9.2
5	Wyoming	978,106	6.7
6	Utah	917,139	6.2
7	Oregon	637,967	4.4
8	Texas	594,287	4.0
9	Arizona	448,806	3.1
10	Washington	405,027	2.8
11	Nebraska	404,481	2.8
12	Louisiana	400,375	2.7
13	Nevada	390,192	2.7
14	New Mexico	371,269	2.4
15	Arkansas	146,910	1.0
16	South Dakota	59,361	0.4
17	Kansas	56,939	0.4
18	North Dakota	10,651	0.07
19	Oklahoma	2,109	0.03
	TOTAL	14,733,252	100.0%

The above includes crops produced within federal irrigation projects which in 1929 included 1,177,584 acres, or about 8 per cent of the total irrigated acreage in nineteen states.

In the western states it is difficult to draw fine lines of distinction between the various types of agricultural enterprises, as many owners of irrigated farms also cultivate non-irrigated tracts and may, in addition, own livestock which is grazed on privately owned or on publicly owned range land or possibly on both. The following table gives a comparison between the irrigated and non-irrigated crop producing acreage in the thirteen western states where irrigation farming is most important.

Comparison of Irrigated and Non-Irrigated

Acreage in 13 Western States

States are listed in order of irrigated acreage.

No.	State	Total Acreage of Non-Irrigated Crops	Total Acreage of Irrigated Crops	Percent of State's Cultivated Acreage under Irrigation
1	California	3,083,377	3,540,350	53.4
2	Colorado	4,469,244	2,291,927	33.9
3	Idaho	1,448,446	1,734,321	54.8
4	Montana	6,535,590	1,343,035	17.0
5	Wyoming	1,022,836	987,106	49.1
6	Utah	283,015	917,139	76.4
7	Oregon	2,223,500	637,967	22.3
8	Texas	30,171,802	594,287	1.9
9	Arizona	51,536	448,806	89.8
10	Washington	3,255,826	405,027	11.1
11	Nebraska	21,027,619	404,481	1.9
12	Nevada	6,577	390,192	98.2
13	New Mexico	1,126,100	371,269	24.3

While this table illustrates the extent of land-use for two general types of farming, it does not give a true picture of their relative importance as the per-acre value of crops produced on irrigated land is generally many times greater than for non-irrigated land.

It is not within the scope of this paper to discuss the relative importance of land-use for cultivated crops as compared with the use of open range lands for production of livestock, but in connection with soil conservation programs for the western states it is necessary to keep in mind that there is a certain definite relationship between these two types of agricultural enterprises.

The foregoing clearly indicates that attempts to develop soil conservation programs for the western states must take into consideration the fact that the primary concern of great numbers of landowners, and even a large part of the general public, has to do with the possibilities of increasing or conserving irrigation water supplies, in attaining greater efficiency in the use of water, and in assuring the maintenance of soil productivity in irrigated areas. In connection with frequent proposals for securing an expansion in irrigated acreage, it is well to note that the possibilities of increasing available water supplies through the construction of large storage reservoirs are extremely limited and that the greatest opportunity for a general improvement in western irrigated agriculture is in the field of improved irrigation farming practices including improvements to distribution systems.

GENERAL PROBLEMS OF IRRIGATION FARMING

Water Laws and Water Rights:

All of the western states have laws governing the use of water for irrigation. Most of these states require that persons desiring to use water must file an application with proper state officials and that a permit for water use be granted before any proposed use becomes legal.

Most of the water laws which have been developed by the western states are based on the theory that all waters are property of the state and that rights to the use of water may be established only by appropriation and use. The following abstract from the "Revised Statutes of Utah for 1933" illustrates this theory:

> "Chapter I, General Provisions.
>
> "100-1-1. The water of all streams and other sources in this State, whether flowing above or under the ground in known or defined natural channels is hereby declared to be the property of the public, subject to all existing rights to the use thereof.
>
> "100-1-3. Beneficial use shall be the basis, the measure and the limit of all rights to the use of water in this State.
>
> "100-1-4. When an appropriator or his successor in interest abandons or ceases to use water for a period of five years the right ceases, and thereupon such water reverts to the public and may again be appropriated as provided in this title.
>
> "100-1-5. The use of water for beneficial purposes, as provided in this title, is hereby declared to be a public use."

Under the common law concerning water rights as developed in the western states, an appropriator acquires no title to water but only the right to its use. This principle is based on the idea that water in an arid region is too precious to be wasted and that prior appropriators do not obtain title to any specific water but only the right to the use of a specific quantity. The common law further provides that if a claimant of a water right cannot use or cannot make the water claimed available for use, he cannot prevent another from using it. No one is entitled to more water for any specific purpose than is reasonably necessary to supply his needs for that purpose, regardless of the quantity that has been used and the length of time it may have been used. Owners of land on which seepage and waste water collects have legal rights to make beneficial use of such percolating waters. Appropriators have the right to store water for future seasonable use, subject always to the rights of

other appropriators. Appropriators are usually entitled to easements over private property for the conveyance of water in natural streams. All matters concerning water rights are subject to judicial determinations.

Many of the available means of increasing efficiency in the use of irrigation water are to some degree affected by existing water rights or by local laws and customs. When irrigation water is diverted directly from small natural streams without the advantages of storage reservoirs, it is the usual custom to make a division of the water to each irrigator on the basis of a certain part of the total supply. In many such streams water rights are classed as to priorities of appropriation. If, for example, three groups of land users have rights of different priority for the entire flow of a small stream with one group having a primary right for all flow up to 10 cubic feet per second, another having a secondary right for all flow from 10 to 15 c.f.s., while the third has a right to the use of flow in excess of 15 c.f.s., it is obvious that the several classes of right are variously affected as seasonal variations in the stream flow occur. If spring opens early and gradually, the high water flow is extended over a long period of time and the largest part of the stream is secured by those holding first priority rights. But if high water comes down in very high flows of relatively short duration, the first priority users are entitled to only a part of the total flow and the holders of second and third priority rights may secure water in abundance for their lands. Obviously under such circumstances and whenever water is available, all of the water users concerned attempt to apply excess quantities to their land with the deleterious effects discussed elsewhere in this report. Under such conditions the construction of new or additional water storage space is justifiably part of a soil conservation program but such developments would necessarily depend upon the ability of the interested landowners to make equitable and adequate adjustments in the water rights involved.

In the law governing water rights, beneficial use is considered to be "the basis, the measure and the limit of water rights". The use of this standard frequently results in practices which are wasteful of both soil and water because by it farmers are sometimes stimulated to irrigate when irrigation is not necessary and to apply water in excess of actual needs because they believe that such use is necessary to protect their rights. Also, since rights of priority in the utilization of limited water supplies are established on the basis of principle that those first in time of use are first in rights of use, the initial efforts of the early settlers to utilize water for irrigation have had an important influence on the irrigation problems of today. The natural tendency of the first settlers on a small stream was to select the diversion point which could be most expeditiously developed and to avoid as much as possible the construction of extensive canal or ditch systems. Thus it naturally came about that the best water rights were not always applied to the best soil and this is a condition still frequently encountered. Thus some forms of water use which are held by the courts to be "beneficial use" are not beneficial in a stricter sense.

An exact interpretation of the term "beneficial use" is so difficult that many persons have urged that it be replaced by the term "economical use". On the other hand, an understanding as to what constitutes "economical use" of water is frequently influenced by the individual user's understanding as to what constitutes the basis for his claimed water right. If the farmer feels that an attempt is being made to measure and limit his water right, he will insist that his needs are greater than can be deduced from a strict analysis of what constitutes economical use. However, from the standpoint of the public in arid regions it is desirable that water be distributed and used in accordance with truly economical duty.

The development of comprehensive conservation programs for irrigated areas may depend in a measure on the correction of misconceptions regarding the true meaning of "beneficial use" or "economical use". It may even be necessary for the public, through the legal means available to it, to interpret the beneficial use doctrine in a way which will tend to correct certain tendencies towards wastefulness in the use of water and stimulate economical methods instead. It is true that there are many things which the individual farmer can be encouraged to undertake but some of the broader problems can be met only by the united action of a majority of the land-users involved. It may be that the requisite of good management in some irrigation enterprises may depend upon public ownership and public stewardship of irrigation systems above the point of delivery to individual farms. It is suggested that the possibility of soil conservation districts undertaking this responsibility is worthy of serious consideration.

Administration of Irrigation Enterprises:

In the formulation of soil conservation programs for irrigated areas, it is necessary to consider that irrigated land-use is usually of a cooperative nature in that water rights most frequently consist of the privilege to use a portion of a given supply. Instances in which the land operator has a right to use water in a manner entirely independent of other rights are relatively rare. The combination of interests involved in nearly all use of water in the West is illustrated by one of the requirements of the laws of Utah bearing on the problem of the joint ownership of irrigation systems which says that "when two or more persons are associated in the use of any dam, canal, reservoir, ditch, lateral, flume, or other means of conserving and conveying water for irrigation of land or for other purposes, each of them shall be liable to the other for the reasonable expenses of maintaining, operating, and controlling the same in proportion to the share in the use or ownership of the water to which he is entitled". Under the common law the point of diversion or even the place of use for water cannot be changed if such change prejudices the rights of others.

Where there is joint ownership of irrigation systems (and this is the usual situation in irrigated areas) there must be some type of organization to administer, operate, and maintain such enterprises. These administrative organizations are of several types which may be classified in general as associations, corporations, and legal districts. With reference to the latter, it is believed that the laws for the establishment of irrigation and drainage districts do not have any great influence on the soil management problems of irrigated areas but the extent of these organizations is so great that a study should be made of their relationship to agricultural programs in the western states.

An important example of the association or corporate type of organization is found in the mutual irrigation company plan as it has been developed in Utah and which is the system of administration used for the greater part of all private irrigation enterprises in this State. A mutual irrigation company is an organization of water users set up for the exclusive purpose of exercising control over irrigation systems and to direct the operation and maintenance of such systems. Mutual irrigation companies may be either incorporated or unincorporated but the incorporated company has some practical advantages. Water under the control of a mutual company organized under the general corporation laws of Utah may be delivered to stockholders only. The active management of a mutual irrigation company is in the hands of a board of directors (or other governing body). The stockholders usually meet annually to elect officers and to decide questions of general policy. Special meetings may be held whenever necessary. The interests of owners of a mutual irrigation company are represented by shares of capital stock, evidenced by certificates, entitling the holders to stated amounts of water or to proportional parts of the total water supply. The free transfer of mutual company stock is permitted.

Mutual companies derive their revenue from assessments upon the capital stock. The Utah corporation law limits single assessments to ten per cent of the outstanding stock but does not limit the number of annual assessments. Limits of assessments are usually fixed by the company bylaws. Assessments are payable in cash or labor or both. Collections of delinquent assessments are enforced by the sale at auction of the stock involved or by the refusal of water services.

Mutual companies usually finance their future needs with money borrowed on notes which are secured by mortgages on the irrigation works. Ordinarily such loans are for small sums which are needed to meet current expenses pending collection of assessments.

The mutual irrigation company is ordinarily concerned only with the operation and maintenance of the main canals and laterals of a system while the maintenance and operation of the distributing ditches is the responsibility of the water user.

Economic Considerations:

The essential factors of a successful irrigation enterprise are high quality soils and reasonable irrigation costs. Because initial investments and current operation costs on an irrigated farm are necessarily higher than for most types of agriculture, the tendency for these costs to exceed feasible limits must be guarded against, crop yields must be maintained at a high level, and the long continued productivity of the land must be assured. The financial distress of many irrigated sections is related to the imposition of inordinate overhead charges, a gradual falling off in soil productivity, attempts to cultivate soils not suited to irrigation farming, and the inability or failure of landowners to adapt their farm management practices to changing conditions.

Under ordinary circumstances the annual overhead cost for irrigated land should not exceed $2.00 per acre for taxes, $2.00 per acre for repayment of irrigation development costs, and $2.00 per acre for irrigation overhead and maintenance. Whenever the aggregate overhead costs to be borne by irrigated land exceeds $6.00 per acre per year, there is little if any chance for a reasonable return to the farmer; he usually loses interest in the enterprise and inefficient farming methods result. Of course, there are many possible exceptions to the general rule concerning permissible overhead charges such as are found in localities with exceptionally favorable climatic conditions which permit the intensive production of highly specialized crops.

Many irrigation enterprises have been initiated on the basis of estimates which were reasonable, but all too frequently the preliminary estimates have been misleading because the development was based on over-optimistic estimates of available water supply, and large proportions of lands not suited to irrigation agriculture were assumed to be capable of bearing a share of the costs. In addition to mistakes in determining the true charges to be borne by lands capable of producing irrigated crops, conditions have frequently developed which required these lands to bear additional costs for drainage, road construction, maintenance of schools and other improvements made necessary by the growth of communities. Through such pyramiding of costs the charges to be borne by irrigated farm lands have often exceeded practicable limits and have become impossible when coupled with any decline in soil productivity. Although modern irrigation began in this region less than one hundred years ago, it has already been demonstrated that long continued irrigation farming is possible only under certain favorable conditions and that the productivity of some irrigated land is relatively short lived. A decline in the productivity qualities of irrigated land is usually the result of the cumulative effects of factors peculiar to irrigation farming such as unfavorable reaction of certain soil to irrigation, alkali accumulations, changing ground water tables and inadequacy of water supplies, all of which problems are later discussed in detail.

The consequences of soil wastage are more serious in irrigated sections than elsewhere because the development of irrigation enterprises requires heavy capital investments, operation and maintenance costs are high, and it is frequently necessary to protect the original investment with additional expenditures for drainage and other necessary works. Inasmuch as entire communities, counties, and states, to say nothing of the landowners and their creditors, are concerned with the successful operation of irrigation enterprises, it is entirely proper that public organizations should assist in the development and actual application of sound irrigation and drainage methods for the conservation of both soil and water, thus helping in the alleviation of financial stresses and in the creation of sound and solvent conditions for irrigated areas.

Water Supplies:

In a great many irrigation communities water is obtained by direct diversion from natural streams and the nature of the water supply not only limits the extent of agricultural development but also has a direct relationship to methods of application and the kind of crops which may be grown. Such limitations are further aggravated in years of drought when the periods of low water supply coincide with seasons in which there is the greatest need for irrigation.

Figures showing average annual precipitation in the western states are usually misleading because wet years may outweigh dry years in computing averages. Also, the dry years tend to come in groups and the damage caused by a drought rapidly mounts with its duration. Also, the average annual precipitation may vary greatly from one section to another. In general (with important exceptions in the northwest) precipitation increases progressively with altitude and occurs mostly in winter and spring. Thus, the greater part of the precipitation in western states falls in mountainous sections in the form of snow, creating a natural reservoir from whence comes a very material portion of the total water supply. This results in a somewhat unequal geographical distribution of water supply with respect to demand and since the greater part of the mountain snow melts in spring and early summer, there is also a problem of seasonal inequality between supply and demand.

Another important problem bearing on water supply is the loss of water in transmission through unlined canals and ditches. The usual percolation losses from this cause are reported to be seldom less than 20 per cent and often reach a high of 60 per cent of the total flow. Soil conservation programs for irrigated areas should include provisions for the determination of losses in canals and ditches. Economic considerations limit the work of placing impervious linings in canals to those sections where measurements indicate that losses are actually taking place. Since under the common law water rights may be established for the use of percolating waters, it is necessary that proposals for the conservation of water by lining of ditches and canals be preceded by thorough investigations concerning the possibility of such works interfering with the rights of other users who may be depending on seepage water which would be shut off by the proposed improvements.

The seasonal nature of water supplies in the West also creates serious flood hazards so that the problem of securing better seasonal distribution of water by means of storage is also related to flood control problems which are of direct concern to the general public.

During recent years a system of snow surveys has been developed in many western states and the information obtained from these surveys constitutes a valuable adjunct to land use programs. Although these surveys are limited in scope, tangible benefits have already been demonstrated. Farmers are enabled to undertake advanced crop planning, contracts for specialized commercial crops (such as sugar beets) may be adjusted to fit the predicted water supply and precautions can be taken against property damage from possible floods produced by abnormally heavy snow covers. Since snow surveys have a decided value in connection with land management planning and in addition may result in direct benefits to entire communities including commercial, banking, and industrial interests, it is desirable that this activity be expanded and correlated with soil conservation programs.

In addition to public undertakings which are necessary to a prediction of seasonal water supplies, it is desirable that soil conservation programs for irrigated areas include provisions for making determinations as to the quality of water used for irrigation with particular reference to the nature and quantity of its saline content and the presence of colloidal material. It is a well known fact that the waters from some streams must be judicially applied in order to avoid adding harmful amounts of alkali salts to the soil while other streams are heavily laden with colloidal material which may have deleterious effects on the soil to which it is applied. Since the proportion of soluble salts and also of suspended colloidal material is usually less when stream flow is high from melting snow, it appears that in some sections the construction of additional facilities for the storage of water may be necessary in order to provide for a mixing of good quality water from high stream flow with the low quality water of low stream flow. It should be noted, however, that this problem is somewhat exceptional. The relationship between quality of water supply and efficient soil management is later discussed in detail.

Duty of Water:

The term "duty of water" is used to indicate the quantity of water required to irrigate a given area of land. The duty of water depends upon the type of crops grown, climate and qualities of the soil to be irrigated. The total quantity of water usually applied during a season varies greatly in different sections and may even vary from farm to farm in a given area. The usual irrigation applications range from about 18 inches per year to 48 inches or more. With respect to variations in water requirements there is found at one extreme those hot arid sections where little or no effective rainfall occurs during the growing season, while at the other extreme are those areas with a cool moist climate where the soil is saturated in the spring and part of the crop requirements are met by rainfall.

If the crops grown are shallow rooted and easily injured by lack of moisture, water must be available at all times during the season. Where deep rooted crops such as trees and alfalfa are grown, irrigation may be delayed for reasonably long intervals of time although maximum crop yields depend upon the maintenance of a certain amount of moisture in the soil. Under especially favorable conditions some kinds of crops can be produced with one or two irrigations. However, infrequent irrigation is usually inefficient irrigation, especially when large quantities of water are available (as in the case of flood flows used for irrigation) and where excessive amounts are applied to the land. Under such circumstances plans for conservation of both soil and water should call for the construction of storage facilities wherever possible in order to provide for more frequent and lighter applications of water, this being one of the usual requirements for conservative irrigation farming.

SOIL MANAGEMENT PROBLEMS IN IRRIGATED AREAS

General Soil Types:

Soils in most irrigated sections may be grouped into three general classes for the purpose of considering soil management problems:

1) The higher lands near the mountains which are usually of shallow depth, coarse texture, high permeability, and with ground water usually far below the surface. These soils are usually highly productive if available moisture is maintained. Percolation losses are large but alkali trouble is rare and productivity is usually well sustained. This type of land may be damaged by excessive applications of irrigation water which causes erosion and which may carry away appreciable amounts of valuable nitrates. In these soils the amount of water consumed by the plant cover is less than the amount of water artificially applied.

2) Lands of medium elevation located between valley floors and higher areas which are usually made up of soils of good depth, average permeability and with the water table usually well below the surface. In some cases deep percolation losses on these soils may be compensated by moisture from ground water which is returned to the root zone by capillary action. On these soils the amount of irrigation water consumed by the plants may be about equal to the amount applied if the application is carefully made although some percolation losses are inevitable.

3) Low lying lands or valley bottom lands which are usually of fine textured soils often having low permeability and with the water table frequently near the surface. In these soils loss of water by deep percolation is negligible. However, soil productivity may be reduced by the rise of the water table which in turn may cause the accumulation of alkali

salts. These soils rarely have natural drainage and artificial drainage is usually needed not only for the disposal of excess ground water but also for the purpose of leaching out accumulated salts, all this being for the purpose of conserving soil productivity. On these soils, when deep rooted crops are grown, the amount of water consumed by the plant growth may actually exceed the amount of irrigation water applied. Thus, from the standpoint of efficiency in utilizing available surface water supplies these lands are of great importance in some areas with particular reference to the production of alfalfa. Occasional heavy applications of irrigation water, if there is adequate drainage, may be needed in order to dispose of alkali by forcing it downward by deep percolation and thence away through artificial drains. Under such circumstances water losses resulting from occasional heavy irrigations are justified.

Any of these three general types of land may be affected by irrigation with respect to fertility and also as to physical characteristics including those that are involved in the absorption, conveyance, and retention of moisture. Thus the sustained productivity of irrigated land frequently depends upon the use of the best known methods of soil and water management.

Alkali Control:

In areas receiving light rainfall one important problem is the accumulation of soluble salts in the soil. This condition is partly due to the aridity of the climate which causes relatively high evaporation from the surface of moist soil. Concentration of alkali salts on the surface due to evaporation of moisture carried to the surface of saturated soils by capillary action, if continued for very long, renders the soil entirely unproductive. Irrigation frequently constitutes a transportation process which conveys water laden with small quantities of mineral in solution from high lands to lower lands or brings soluble salts to the surface of the area irrigated. As a result of these conditions large areas have been made non-productive or at least unprofitable. Thus, alkali lands are common in arid sections and it is a matter of concern that alkali tracts are gradually increasing in number and size.

However, some of these so-called alkali lands are made up of soil which contains abundant plant food elements and the alkali condition is frequently confined to the first few inches of the topsoil. Many of these tracts have possibilities for effective utilization if economical methods for their reclamation are applied. Parts of many individual farms now lying idle because of alkali accumulations could be used for intensive farming to the distinct advantage of the community if proper account is taken of the fundamental principles involved in proper methods of irrigation and drainage.

A knowledge of the quantity and nature of the saline content of water used for irrigation is necessary to the systematic planning of irrigation methods, cultural methods, kinds of crops grown, and crop rotations employed. However, the mere determination of the quantity of salts present in irrigation water does not solve the problem unless this knowledge is properly associated with information concerning the soils upon which the water is to be used. For example, the use of saline irrigation water on open, well-drained, sandy soil might be permissible whereas the use of the same water on fine textured, poorly-drained soil would result in disaster.

In all instances where the soil itself or the irrigation water contains harmful alkaline salts, periodic heavy irrigations or irrigations heavy enough to give a leaching effect on that particular soil must be used in order to keep the salts moving away through drainage systems. Thus the purpose of drainage may be twofold involving both the disposal of surplus subsoil water and the removal of the salts that are continually being brought to the land in irrigation water. The necessity for occasional heavy irrigations on some soils suggests that the providing of additional storage for water and the installation of drainage facilities may be an important factor in dealing with the land-use problems of some sections.

In summing up the problems of alkali control it may be said that it is a known fact that the dissolved salt constituents of soil and water do accumulate on irrigated land and do impair its productivity and that this is one of the fundamental problems to be met in maintaining a permanent irrigation agriculture. It is also known that the accumulation of soluble salts may result either from improper irrigation practices or from inadequate drainage, that the effect of salt accumulations are seldom immediately apparent and if not attacked promptly may progress to a point where remedial measures are expensive and in some cases impracticable. Thus, soil conservation programs for most irrigated areas should include provisions for the frequent sampling and analysis of soil salts and the sampling and analysis of irrigation and drainage water in order that the effects on the soil of prevailing irrigation and drainage practices may be observed.

Ground Water Control or Drainage:

An important problem in irrigation farming arises from the fact that in most, if not all, irrigation areas, irrigation and drainage are complementary practices or that irrigation practices have a direct influence on drainage problems. Vast acreages of valuable land have been ruined by irrigation and the usual history of an arid valley reclaimed by irrigation is that some of the lower land which was at first the most productive is eventually ruined by water-logging, by alkali accumulations resulting from the application of water to higher lands, or by seepage from unlined canals or from canals built in embankments above the surrounding land.

Technicians engaged in the preparation of conservation plans for irrigated farms where control of the ground water table is a problem should carefully consider the relationship between the known ground water problem and prevailing irrigation practices on the farm in question. There is a lesson in the fact that large sums of money have been spent in some sections for extensive drainage works only to discover later that the adoption of conservative irrigation practices or the placing of impervious linings in certain canal sections would have rendered some of the drainage installations unnecessary besides greatly increasing efficiency in the use of available water supplies.

Drainage of farm land in arid sections may have one or more major objectives: (1) There may be a necessity for the removal of excess water from the soil in order that crop production be freed from limitations imposed by height of ground water table. In this connection it is well to note that plants require an aerated root zone, a requirement which may be met in some cases only by the establishment of artificial subsoil drainage. Lack of aeration may limit crop production even when the supply of plant nutrients is adequate. (2) Drainage may be especially important because of the relatively large quantities of soluble salts in the soil or in the water used for irrigation. Under such circumstances lack of drainage will result in an accumulation of salts with detriment not only to the growing plants but to the soil itself. Thus, drainage may be necessary in order to leach excess soluble salts from the soil in order to improve or maintain soil productivity. (3) Drainage may be necessary in special cases for the purpose of facilitating farm operations or even for improving health conditions on the farm.

There are many individual farms where independent drainage systems may be successfully installed but the movement of ground water, like that of surface water, takes place without respect to property lines and it is frequently impossible to attach drainage operations to any particular farm, especially if that farm be small. Thus the control of ground water may be a public problem with the ultimate solution depending to some extent upon public works supported by public regulations and public control. It may be possible in some cases to promote drainage works through the medium of soil conservation districts in order to serve community interests and to avoid the difficulties that have sometimes resulted in the past from the application of commercial or profit-motivated methods.

Soil conservation programs in irrigated areas should include provisions for the assignment of technicians to the solution of drainage problems. Because of the complicated nature of ground water control, careful and detailed study is necessary for all farms requiring drainage. In order to provide for proper irrigation practices and for the practical design and location of drainage systems such studies should include: construction of wells and borings for the determination of ground water levels, and for observations as to the relationship between irrigation practices and ground water tables; and the preparation of maps to show topography and the relationship that ground water tables have to the surface of the area to be treated.

Erosion Control on Irrigated Farms:

Although erosion is only one of many soil management problems connected with irrigation farming, it is frequently encountered and often receives too little attention. Erosion on irrigated land is ordinarily caused by excessive irrigation grades, by an improper application of irrigation water, and by lack of an adequate waste water disposal system. Therefore, the obvious remedies for controlling erosion on irrigated land include the proper preparation of the land by leveling, provisions for waste water disposal, installation and use of headgates and outlet boxes or other controlling devices to secure proper subdivision of flow, and control of irrigation heads. Farm land contiguous to a channel is especially susceptible to damage by headcutting erosion as well as by sheet erosion, particularly when the waste water is not thoroughly controlled. Soil saving dikes (located a safe distance from the channel) with controllable waste water outlets are frequently required. In many cases such dikes will not only take care of the waste water disposal problem but will also assist in checking the loss of fertile topsoil.

Erosion of irrigated land is not only a wastage of soil and water, it eventually results in increasing the amount of labor required in applying the water. Irrigation farming is frequently made more difficult by erosion in ditches, canals, or natural channels forming part of the distribution system. Methods for controlling this sort of erosion may necessitate the installation of paving, riprapping, cross checks, drops or pipes in the ditches or canals. In the natural channels there may be a need for bank protection works such as revetments, levees, and jetties, together with indicated woody and herbaceous plantings.

In the formulation of soil conservation programs for irrigated areas emphasis should be placed on the fact that there is a direct relationship between the efficient utilization of water and measures for control and prevention of erosion. For example, the careful control of irrigation water to reduce surface runoff (that is, to eliminate the flow of waste water from a given field) serves to reduce both soil erosion and the gross water requirement. Or, the proper preparation of land for irrigation which is necessary to secure efficiency in use of water also results in erosion control. The direct relationship that exists between soil conservation and water conservation (in nearly all phases of land management for irrigated areas) is further illustrated by the fact that the greatest efficiency in the use of water and the least danger of erosion occurs on soils which are high in organic content. For example, the application of manure to the soil helps to maintain its fertility and increases its moisture holding capacity, and this treatment also serves to reduce erosion because as a rule organic matter increases soil aggregation thus making the soil less erosive.

If, in the preparation of farm management plans for irrigated lands, the principal concern of the land operator is with the conservation of available water supply, the problem of determining proper land-use practices for that particular tract may just as well be approached on the basis of water conservation since soil conservation (in the strictest sense) naturally follows any improvement in irrigation methods and practices.

Maintenance of Soil Fertility:

When the prevailing practices on irrigated farms are viewed in relation to maintenance of soil productivity, we find that various irrigation practices are by comparison either conservative or wasteful. Heavy irrigations noticeably reduce the fertility of the soil, especially when measured by nitrates. Not only does irrigation affect the immediate yield of crops to which it is applied but because of its effect on soil fertility and subsurface conditions, it also has an influence on the ability of the land to produce crops in following years and this harmful effect (with reference to rising ground water tables) may even extend to neighboring farms.

Thus it appears that maintenance of fertility is one of the more serious problems encountered in irrigation farming. This comes about in part from the fact that a common deficiency in many of the soils of arid regions is the lack of organic material. The failure of many early irrigation enterprises was due to this deficiency, a situation which was aggravated by the optomistic belief on the part of some that water is the primary factor in an irrigation enterprise and that the quality of the soil to which this water might be applied is a matter for secondary consideration. Some areas once successfully used for dry farming and for which irrigation water was later supplied have been disappointing because of a failure to recognize that profitable dry farming is possible with soils having considerably less organic content than is needed in soils for irrigation farming.

The application of barnyard manure is the most satisfactory method of adding organic matter to the soil for the correction of physical conditions. This practice also results in the stimulation of bacterial activity and the influence of acids developed during decomposition of the manure in changing soil phosphates into a form available to plants. Because the continuous cropping of most irrigated land is impossible unless humus is added to the soil in order to develop and maintain a suitable soil structure, it is apparent that irrigation farming is most likely to be successful when coupled with the production of livestock provided manure supplies are carefully conserved and applied to the land.

The nitrogen content of the soil in many irrigated areas is low; therefore, a good rotation system, including the occasional use of a cultivated crop and of a leguminous crop such as alfalfa or clover on each field is an important means of maintaining productivity. The use of cultivated crops helps to control weeds and aerates the soil which makes the plant food materials, especially nitrogen, more available to the plants. Alfalfa or the clovers gather nitrogen from the air and the extensive root systems of these plants aid in improving the physical conditions of the soil. However, efforts to increase the nitrogen content of the soil are in vain unless coupled with proper irrigation practices. Irrigation increases the speed with which nitrogen is rendered soluble in the soil but excess water may carry the readily soluble nitrogen beyond the feeding area of the plants. Hence the nitrogen available to the plant proportional to its requirements may be reduced under heavy or careless irrigations where, under the same conditions, a system of light applications would result in soil improvement.

Soil conservation programs for irrigated areas should provide for the development and application of information for each farm concerning the fundamental conditions of its soil, the reaction of this soil to the application of irrigation water, and the effects that are produced on the soil by the continuous growing of irrigated crops.

Conservation of Soil Moisture and of Water Supplies:

Although a great deal of emphasis is often placed on the saving of water which is lost before it reaches the farm, the problem of attaining efficiency in the actual application of water to the land is frequently neglected. The question of water application efficiency is one which should be given particular attention in the preparation of all farm management plans for irrigated areas. Inefficiency in the application of water is not only wasteful of supplies but such practices usually have deleterious effects on the soil. Some of the adverse effects of inefficient or excessive irrigations are rising ground water tables and accumulations of alkali on low lands, the leaching of solvent nutrients from the soil, and the loss of soil by erosion.

"Water application efficiency" by the most commonly used definition of the term means "the percentage of water applied that can be accounted for as soil moisture increase in the soil occupied by the principal rooting system of the crop". Water application efficiencies are influenced by a variety of factors. Some of these, such as the texture, depth, and permeability of the soil, may vary greatly from place to place on a farm and are not subject to control by the farmer. The principal factors which are subject to the farmer's control are the methods used in applying water, quantities of water used and the time rate of application, and the adequacy of land preparation prior to irrigation.

Soil moisture is lost from irrigated land by transpiration through plants, surface evaporation, and deep percolation. There is no way in which transpiration losses can be reduced although proper fertilization and good cultural practices will increase crop production in proportion to the total amount of water consumed. Surface evaporation is affected to some extent by the length of time and the amount of water applied, but aside from the possibilities of controlling this factor there are few feasible methods of reducing evaporation losses and these may be employed only under certain favorable conditions. For example, on some soils and with some crops artificial mulches of straw, paper, etc., and natural mulches produced by cultivation may be used to reduce soil moisture losses by evaporation.

Thus, from a practical viewpoint particular attention must be given to the problem of soil moisture losses by deep percolation. Since deep percolation (and also waste of water by surface runoff during irrigation) is due to improper handling of water, it follows that reductions in soil moisture losses must be brought about almost entirely by improvements in irrigation practices coupled with proper seasonal distribution and regulation of water supply. It is a well known fact that deep percolation

losses, being concealed, are frequently under-estimated. Therefore, careful measurements of the volume of water applied to every tract at each irrigation are necessary for the purpose of revealing actual water losses resulting from inefficient methods of application. Farm management plans should include provisions for the installation of appropriate water measuring devices and the keeping of complete records relative to the use of irrigation water on the farm.

Experiments indicate and demonstrations have proven that the maximum economy in the use of irrigation water is secured by the use of small and relatively frequent applications so that soil within the zone of root growth may absorb all of the water applied before it has time to percolate to lower depths. The general rule that light applications are best is based on the fact that each irrigation increases the moisture in the upper portions of the soil more than the lower depths so that light applications have a great proportionate influence on soil moisture available to the crop than is obtained by heavier applications. The rule that relatively frequent applications are desirable is based on the fact that soil when too dry does not increase in moisture content as rapidly after irrigation as if the moisture content were just right. Thus, from a practical standpoint it is desirable that light irrigations be made at proper intervals, the frequency of which is determined by the moisture content of the soil at any given time. Provisions for proper frequency and limitations as to the amount of water to be applied at any single irrigation should be included in farm management plans.

With regard to distribution of water supply, it is necessary to recognize that maximum application efficiencies (and this includes conservation of soil moisture) cannot be secured unless the water user is assured of constant and adequate flows during the irrigation period. One somewhat exceptional example of this problem is found on small streams where there is a wide daily fluctuation of stream flow with the peak flow frequently coming at night, which makes the proper handling of water an extremely perplexing problem. Under such circumstances small equalizing reservoirs are necessary to the adoption of good irrigation practices. A more common and also more important requirement in most irrigated areas is the need for adequate water storage in order to assure proper seasonal distribution of water. When faced with an abundant water supply during the spring and early summer months and an assured water shortage during the late summer and fall months, many farmers make the mistake of attempting to conserve the water by over-irrigating when the water is available. Such a practice is wasteful of water that might be beneficially used in some lower area, often contributes to the waterlogging of contiguous lower land, contributes to excess leaching of plant food, is often harmful to the growing crops and to the soil. It would appear, therefore, that for those areas where adequate storage facilities are impossible, farm management plans should be made only after a careful consideration of those crops most adaptable to the average moisture conditions for the season with stress being given to the proper use of available irrigation water.

Since the proper amount of irrigation water to be used in any given case is determined by a variety of physical and economic factors that change with each set of conditions, it is impossible to promote water

application efficiencies on particular farms through the usual educational means. That is to say, the maximum development of efficient methods in irrigated areas can be secured only by making technical personnel and other forms of assistance directly available to irrigation farmers who desire to improve their land-use practices. In order to properly advise farmers as to the most efficient use of irrigation water, planning technicians must know for each field the texture and structure of the soil and subsoil and depth of each, efficiency of subsurface drainage, water holding capacity of the soil, and the approximate seasonal moisture requirements for the different adaptable crops.

Plans for securing efficiency in the use of irrigation water must usually be developed with individuals but many problems concerning the conservation of available water supply will require the cooperation of entire groups. Such group problems will usually concern the major elements of an irrigation system such as headworks, storage and regulating reservoirs, canals and ditches to carry water to points of delivery, and the problem of administering and distributing water to the individual users. The bringing about of logical water distribution policies which will reward skillful and intelligent use of water and penalize guesswork and careless methods is a particularly important matter requiring group action. Where independent irrigation enterprises have constructed numerous ditches in relatively small areas, group action will be needed to effect the consolidation of irrigation systems in order to eliminate waste of water and duplication of effort.

The initiative for such group actions as have been suggested above should come from the interested parties but it may often be necessary for them to enlist the support of public agencies in order to overcome opposition on the part of the few who fear that their established water rights are to be in some way compromised by the effectuation of local soil and water conservation programs. The disinterested position of certain federal and state agencies may enable them to perform important public services in such situations. In this connection it is suggested that organized soil conservation districts may serve as a useful medium for the promotion of cooperation between landowners having related interests and who desire to carry out conservation programs for irrigated areas. It is possible that the placing of some irrigation systems under the control of a local organization having public functions (such as a soil conservation district) would pave the way for the improvement of existing irrigation systems in a manner which would be to the best advantage of the community. The transfer of ownership and control of these irrigation systems from private organizations to a governmental unit should bring about general benefits such as decreased costs for maintenance, more orderly distribution and more economical use of water, and transfer of water from poor lands to better lands. Besides, through such a public organization, competent technical assistance could be made available to land operators desiring to improve their irrigated land-use practices.

Noxious Weeds and Plant Diseases:

Irrigated areas appear to be highly susceptible to the spread of noxious perennial weeds. This results from the fact that irrigation waters furnish an ideal transportation medium for many weed seeds. Ditch banks and other lands occupied by distribution systems do not lend themselves readily to cultivation for weed control, and abandoned farms and watershed areas produce weeds which spread readily to the cultivated areas by the means noted above.

The importance of noxious weed control is indicated by one approved soil building practice in the 1940 A.A.A. program in Utah where payments of $7.50 per acre are allowed for the eradication of perennial noxious weeds on seriously infested plots. In this program credit is given for the control of the following weeds: Canada Thistle, Bind Weed or Morning Glory, White Top, Leafy Spurge, Perennial Ragweed, and Russian Knap Weed.

Also, it is known that the presence of injurious plant diseases or root parasites is becoming increasingly more common in certain irrigated areas. A change in the type or kind of crops grown may be necessary to meet this condition. In some localities the accomplishment of needed changes in cropping systems may be brought only by providing additional water storage facilities in order to secure the seasonal distribution of water that may be necessitated by the new substitute crops. At any rate, it is apparent that policies adopted for soil conservation work in irrigated areas should take into consideration the problems resulting from the presence of noxious weeds and plant diseases.

Adaptation of Crops to Irrigation Farming:

Some irrigation enterprises possess a wide range of crop adaptation whereas in other situations the number of important crops that can be successfully grown are quite limited. Also, it is observed that many areas of soil once favorable for a particular crop are no longer suitable for that crop because of modifications brought about in the soil by the effects of irrigation.

Variations in the quantities of irrigation water applied to crops not only affect the total yield of dry matter but also the composition of the plant itself. This fact has been brought out by numerous investigations undertaken at the agricultural colleges and elsewhere. The 1939 Yearbook of Agriculture indicates the popularization of knowledge concerning the nutritive value of harvested plants and the relationship of this factor to the food requirements of both men and animals. Some experiments have demonstrated, for example, that corn grown under irrigation is more valuable for human and animal nutrition than similar corn grown without irrigation.

Because the irrigation farmer is able, within certain limits, to regulate the kind and quality of crops grown, it is quite possible for him to produce agricultural products of superior quality. This suggests

a possible means of overcoming some of the economic handicaps attached to irrigation farming. Hence there may be occasions to consider this possibility in connection with the preparation of farm conservation plans.

Summary:

As pointed out herein, comprehensive and coordinated programs for soil conservation and erosion control in irrigated areas should be based on a careful consideration of a variety of problems commonly associated with irrigation farming.

Many of these problems are such that they may be met only by action on the part of organizations having power and authority to provide for the construction, maintenance, operation, and administration of the major elements of a given irrigation system. Furthermore, it is frequently difficult or impossible for irrigation farmers to effectively carry out soil conservation plans on their lands until certain adjustments or developments have been made by the group with which they are associated.

Some of the more important problems which ordinarily require group action are: adoption of water distribution policies which reward conservative use of water and penalize wasteful use; equitable adjustments in water rights to overcome objections to proposals for improvements in irrigation systems; construction of storage and equalizing reservoirs; and the distribution of costs for water storage projects between landowners whose capital assets are increased and the public which secures flood control and other benefits from such developments. In some cases the effectuation of necessary measures may call for the ownership, control, or regulation of irrigation systems and water supplies by legal organizations having authority to perform public functions.

Assistance to individual landowners in the preparation and effectuation of soil conservation and land management plans for irrigated farms should usually be conditioned on the willingness and ability of the cooperator to include the following in the adopted plan:

1. Installation of water measuring devices and provisions for the keeping of complete and detailed records as to the amount of water used on each particular tract covered by the plan.

2. Specified irrigation practices for each cultivated tract with particular reference to size and gradient of ditches, size of ditch outlets, length of irrigation runs, and size of irrigation head to be used.

3. Limitations as to the maximum amount of water to be applied at any single irrigation and provisions concerning the time and frequency of irrigation with reference to soil moisture conditions and the needs of particular crops.

4. Specified general practices for the conservation of soil and water including cultural methods, land preparation,

installation of headgates and other water control devices; erosion control structures in ditches and canals; and installation of drainage systems where necessary.

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